



(19)

Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 0 949 255 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
13.10.1999 Bulletin 1999/41

(51) Int. Cl.⁶: C07D 311/72

(21) Application number: 99106507.9

(22) Date of filing: 30.03.1999

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 06.04.1998 EP 98106237

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(54) **Process for manufacturing d, 1-alpha-tocopherol in a carbonate solvent and in the presence of a sulphur-containing acid catalyst**

(57) A process for the manufacture of d,l-alpha-tocopherol by the acid catalyzed condensation of trimethylhydroquinone with isophytol comprises carrying out the condensation in the presence of at most 0.4 weight percent based on the weight of isophytol of sulphuric acid, methanesulphonic acid, ethanesulphonic acid, trifluoromethanesulphonic acid, p-toluenesulphonic acid or fluorosulphonic acid in ethylene or propylene carbonate or a mixture of both carbonates, or in a mixture of one or both of the carbonates and a non-polar solvent. The product of the process is the most active and industrially important member of the vitamin E group.

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Description

[0001] The present invention is concerned with a novel process for the manufacture of d,l- α -tocopherol by the acid-catalyzed condensation of trimethylhydroquinone (TMHQ) with isophytol (IP) in a solvent. As is known, d,l- α -tocopherol is a diastereoisomeric mixture of 2,5,7,8-tetramethyl-2-(4',8',12'-trimethyl-tridecyl)-6-chromanol (α -tocopherol), which is the most active and industrially most important member of the vitamin E group.

[0002] Many processes for the manufacture of d,l- α -tocopherol by the condensation of TMHQ with IP in the presence of various catalysts or catalyst systems and in various solvents are described in the literature. These processes go back to the work of Karrer et al., Bergel et al. as well as Smith et al. [see *Helv. Chim. Acta* **21**, 520 et seq. (1938), *Nature* **142**, 5 36 et seq. (1938) and, respectively, *Science* **88**, 37 et seq. (1938) and *J. Am. Chem. Soc.* **61**, 2615 et seq. (1939)]. While Karrer et al. carried out the synthesis of d,l- α -tocopherol from TMHQ and phytol bromide in the presence of anhydrous zinc chloride ($ZnCl_2$; a Lewis acid), not only Bergel et al. but also Smith et al. used TMHQ and phytol as starting materials. In the following years mainly modifications, e.g. alternative solvents and Lewis acids, were developed. From the work of Karrer et al. there was developed in the year 1941 a technically interesting process for the manufacture of d,l- α -tocopherol which was based on the condensation of TMHQ with IP in the presence of the catalyst system $ZnCl_2$ /hydrochloric acid (HCl) (US Patent 2 411 969). Later publications, e.g. Japanese Patent Publications (Kokai) 54380/1985, 64977/1985 and 226979/1987 [Chemical Abstracts (C.A.) **103**, 123731s (1985), C.A. **103**, 104799d (1985) and, respectively, C.A. **110**, 39217r (1989)], describe this condensation in the presence of zinc and $ZnCl_2$ and a Bronsted (protic) acid, such as a hydrohalic acid, e.g. HCl, trichloroacetic acid, acetic acid and the like, especially $ZnCl_2$ /HCl, as the catalyst system. Disadvantages of these and further published processes featuring $ZnCl_2$ in combination with a Bronsted acid are the corrosive properties of the acids and the contamination of the waste water with zinc ions as a result of the large amount of $ZnCl_2$ required for the catalysis.

[0003] The manufacture of d,l- α -tocopherol by the reaction of TMHQ with phytol chloride, phytol or isophytol in the presence of boron trifluoride (BF_3) or its etherate ($BF_3 \cdot Et_2O$) is described in German Patents 960720 and 1015446 as well as in US Patents 3 444 213 and 4 634 781. However BF_3 too has corrosive properties.

[0004] Also, the condensation of TMHQ with IP or another phytol derivative in the presence of a Lewis acid, e.g. $ZnCl_2$, BF_3 or aluminium trichloride ($AlCl_3$), a strong acid, e.g. HCl, and an amine salt as the catalyst system is described in European Patent Publication (EP) 100471. In an earlier patent publication, DOS 2606830, the IP or phytol is pretreated with ammonia or an amine before the condensation with TMHQ in the presence of $ZnCl_2$ and an acid is effected. In both cases corrosion problems occur.

[0005] A further interesting method for the manufacture of d,l- α -tocopherol from TMHQ and IP comprises using an isolated TMHQ- BF_3 or - $AlCl_3$ complex as the catalyst and a solvent mixture featuring a nitro compound (DOS 1909164). This process avoids to a large extent the formation of undesired by-products because it involves mild reaction conditions. The yield of d,l- α -tocopherol, based on IP and the use of the solvent mixture methylene chloride/nitromethane, is given as 77%. However, the use of such a solvent mixture is disadvantageous.

[0006] The manufacture of d,l- α -tocopherol by the condensation of TMHQ with IP using cation exchange complexes of metal ions (Zn^{2+} , Sn^{2+} and Sn^{4+}) is disclosed in *Bull. Chem. Soc. Japan* **50**, 2477-2478 (1977); amongst other disadvantages it gives the desired product in unsatisfactory yields.

[0007] The use of macroreticular ion exchangers, e.g. *Amberlyst*[®] 15 as the catalyst for the condensation of TMHQ with IP is described in US Patent 3459773.

[0008] EP 603695 describes the manufacture of d,l- α -tocopherol in liquid or supercritical carbon dioxide by the condensation of TMHQ with IP in the presence of acidic catalysts, such as $ZnCl_2$ /HCl and ion exchangers.

[0009] The condensation in the presence of a catalyst system which consists of iron(II) chloride, metallic iron and HCl gas is described in DOS 2160103 and US Patent 3789086. The formation of less byproducts is advantageous compared with the aforementioned process using $ZnCl_2$ /HCl. However, corrosion problems and chloride contamination are equally disadvantageous.

[0010] An interesting alternative for the condensation of TMHQ with IP to d,l- α -tocopherol comprises using trifluoroacetic acid or its anhydride as the catalyst (EP 12824). Although in this process the avoidance of HCl is achieved, the alternative catalyst is relatively expensive.

[0011] The use of heteropolytungsten acids as catalysts for the condensation of TMHQ with IP was described for the first time in *React. Kinet. Catal. Lett.* **47**(1), 59-64 (1992). d,l- α -Tocopherol could be obtained in about 90% yield with this process using various solvents.

[0012] A further process described in the literature [EP 658552; *Bull. Chem. Soc. Japan* **68**, 3569-3571 (1995)] for the synthesis of d,l- α -tocopherol is based on the use of a scandium, yttrium or lanthanide fluorosulphonate, nitrate or sulphate, e.g. scandium trifluoromethanesulphonate. With up to about 10% excess of IP this process gives yields up to 98%.

[0013] The use of ion exchanged bentonite, montmorillonite or saponite through treatment with e.g. scandium chloride and other metal salts (yttrium, lanthanum, etc.) as the catalyst for the condensation of TMHQ with IP has as a disad-

vantage the need for a large amount of catalyst [EP 677520; Bull. Chem. Soc. Japan 69, 137-139 (1996)].

[0014] According to the Examples of EP 694 541 the condensation of TMHQ with IP to α -tocopherol can be achieved in high yields and with a high product purity when such solvents as carbonate esters, fatty acid esters and mixed solvent systems are employed, catalysis being effected by $ZnCl_2/HCl$. Disadvantages in this process are, in addition to the contamination of the waste water by zinc ions, the usual large "catalyst amount" of $ZnCl_2$ used.

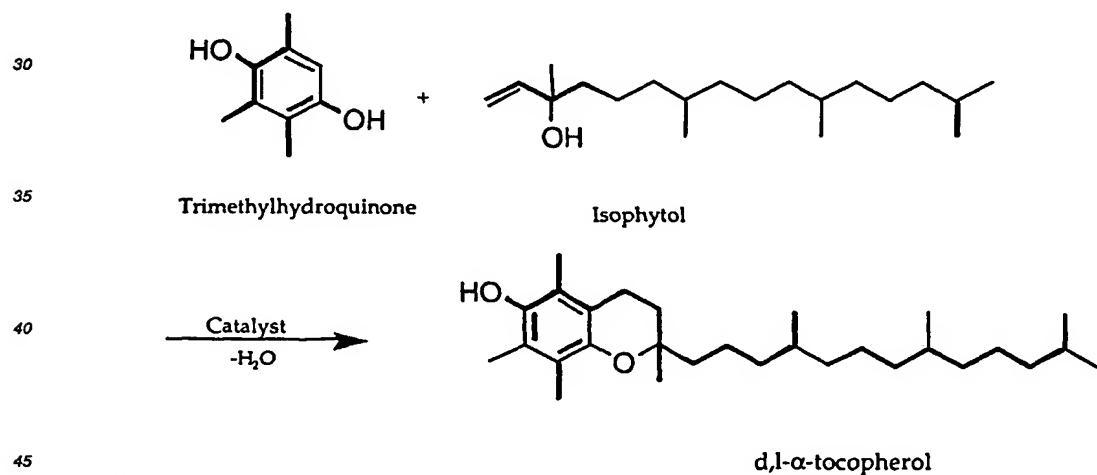
[0015] According to WO 97/28151 the acid-catalysed condensation of TMHQ with IP can be performed in a cyclic carbonate or α -lactone as the solvent. The preferred catalyst is a mixture of ortho boric acid and oxalic, tartaric or citric acid, or boron trifluoride etherate.

[0016] From the forgoing explanations it is evident that most of the previously known processes have considerable disadvantages. Thus, corrosion problems occur in all processes in which such acid catalysts as boron trifluoride are used. Toxicity problems with the boron trifluoride adducts also occur, and when iron or zinc is used there is a contamination of the waste water with the metal ions which is today no longer acceptable. In some processes the formation of undesired byproducts, e.g. phytoltoluene and chlorophytols, is an especially serious problem.

[0017] The object of the present invention is to provide a process for the manufacture of d,l- α -tocopherol by the condensation of trimethylhydroquinone with isophytol in the presence of a catalyst and in a solvent which does not have the disadvantages of previously known procedures. In this respect, it is necessary that the catalyst used has no, or at least a much reduced, corrosive action, is non-toxic, does not contaminate the environment and catalyzes the desired reaction as selectively as possible and in high yields. Furthermore, the catalyst should display its activity already in small, really catalytic, amounts, and should be readily separable and re-usable several times.

[0018] This object of the present invention is achieved by carrying out the condensation of trimethylhydroquinone with isophytol in the presence of at most 0.4 weight percent based on the weight of isophytol of one of the following sulphur-containing acid catalysts: sulphuric acid, methanesulphonic acid, ethanesulphonic acid, trifluoromethanesulphonic acid, p-toluenesulphonic acid and fluorosulphonic acid, so rendering the use of a Lewis acid unnecessary. Furthermore, condensation is effected in ethylene or propylene carbonate or a mixture of both carbonates, or in a mixture of one or both of the carbonates and a non-polar solvent as the solvent or (two-phase) solvent system, as appropriate.

[0019] The condensation itself is represented in the following Reaction Scheme, which is presented conventionally:



[0020] Thus, the process in accordance with the invention for the manufacture of d,l- α -tocopherol by the acid-catalyzed condensation of trimethylhydroquinone with isophytol in ethylene or propylene carbonate or a mixture of both carbonates, or in a mixture of one or both of the carbonates and a non-polar solvent, is characterized by carrying out the condensation in the presence of at most 0.4 weight percent based on the weight of isophytol of an acid catalyst selected from sulphuric acid, methanesulphonic acid, ethanesulphonic acid, trifluoromethanesulphonic acid, p-toluenesulphonic acid and fluorosulphonic acid.

[0021] If in addition to ethylene or propylene carbonate or a mixture of both carbonates and a non-polar solvent is employed, said non-polar solvent is suitably an aliphatic hydrocarbon, e.g. hexane, heptane or petroleum ether, preferably heptane.

[0022] The condensation is conveniently effected at temperatures from about 50°C to about 150°C, preferably from

about 80°C to about 120°C, especially at about 100°C.

[0023] Furthermore, trimethylhydroquinone is conveniently used in a molar excess over isophytol of about 30 to 65%, preferably about 50%. The amount of acid catalyst is conveniently about 0.1 to 0.4 weight percent, preferably about 0.1 to 0.2 weight percent, based on the weight of isophytol.

[0024] If the reaction is carried out in the presence of both a carbonate (ethylene or propylene carbonate, or both) and a non-polar solvent, then the volume ratio of the non-polar solvent to the carbonate used in the two-phase solvent system is conveniently in the range from 0.3:1 to 5:1. The (total) amount of carbonate solvent, i.e. ethylene carbonate and/or propylene carbonate is conveniently about 10 to 100 ml, preferably about 10 to 50 ml, per 100 mmol of trimethylhydroquinone, and if a non-polar solvent is additionally used, conveniently about 50 to 150 ml, preferably about 70 to 120 ml, of said non-polar solvent are used per 100 mmol of isophytol. In any event, only the one or the other carbonate is preferably used, either as the sole solvent or as the carbonate component of the two-phase solvent system with the non-polar solvent. As the latter, heptane is preferably employed, and the carbonate itself is preferably ethylene carbonate.

[0025] Moreover, the condensation is conveniently carried out under an inert gas atmosphere, preferably gaseous nitrogen or argon.

[0026] As the acid catalyst there is preferably used sulphuric acid or p-toluenesulphonic acid.

[0027] The process in accordance with the invention can be carried out operationally in a very simple manner by adding isophytol alone or a solution of isophytol in the optionally employed non-polar solvent dropwise to a solution or suspension of the trimethylhydroquinone and the acid catalyst in ethylene or propylene carbonate or a mixture of both carbonates. The rate at which the isophytol is added is not critical. Conveniently, isophytol is added dropwise over a period of 0.1 to 1, preferably 0.3 to 0.5, hour. After completion of the isophytol addition and an appropriate subsequent condensation, during which it is advantageous to remove the resulting water by azeotropic distillation or in the flow of inert gas used, isolation and purification of the obtained d,l- α -tocopherol can be effected by procedures conventionally used in organic chemistry, e.g. by distillation.

[0028] Particular advantages in the use of the acid catalyst in the process in accordance with the invention are, in addition to high yields of d,l- α -tocopherol, the avoidance of waste water contamination with heavy metal ions, the high selectivity as well as the enabled ready isolation of the produced d,l- α -tocopherol from the mixture after reaction, in particular from the unreacted trimethylhydroquinone.

[0029] The process in accordance with the invention is illustrated by the following Examples:

Example 1

[0030] To a mixture of 23.3 g (150 mmol) of 2,3,5-trimethylhydroquinone (98% pure), 80 ml of ethylene carbonate (99% pure) and 0.14 ml of 10% (v/v) sulphuric acid (0.25 mmol), a solution of 31.21 g (100 mmol) of isophytol (95% pure) in 100 ml of heptane was added dropwise under an argon atmosphere and with stirring at 100°C over a period of 20 minutes. During the addition of isophytol an azeotropic mixture of water/heptane was separated with the help of a water separator. After completion of the addition, the reaction mixture was stirred for another 30 minutes with removal of heptane. The internal temperature rose to about 145°C. After cooling the reaction mixture to about 90°C, 200 ml of heptane were added and the mixture was stirred for about 5 minutes. The upper layer was separated and the lower carbonate layer was extracted with a further 100 ml of heptane. The combined heptane layers were washed with 20 ml of water. After removal of heptane by evaporation 43.76 g (95.6% yield) of d,l- α -tocopherol were obtained as a brown oil [purity as determined by gas chromatographic (GC) analysis: 94.1%].

Example 2

[0031] To a mixture of 23.3 g (150 mmol) of 2,3,5-trimethylhydroquinone (98% pure), 80 ml of ethylene carbonate (99% pure) and 0.28 ml of 10% (v/v) sulphuric acid (0.50 mmol), a solution of 31.21 g (100 mmol) of isophytol (95% pure) in 100 ml of heptane was added dropwise under an argon atmosphere with stirring at 100°C over a period of 20 minutes. During the addition of isophytol an azeotropic mixture of water/heptane was separated with the help of a water separator. After completion of the addition, the reaction mixture was stirred for another 30 minutes with removal of heptane. The internal temperature rose to about 145°C. After cooling the reaction mixture to about 90°C, 200 ml of heptane were added and the mixture was stirred for about 5 minutes. The upper layer was separated and the lower carbonate layer was extracted with a further 100 ml of heptane. The combined heptane layers were washed with 20 ml of water. After removal of heptane by evaporation 43.71 g (95.6% yield) of d,l- α -tocopherol were obtained as a brown oil (purity according to GC analysis: 94.2%).

Example 3

[0032] To a mixture of 93.18 g (600 mmol) of 2,3,5-trimethylhydroquinone (98% pure), 80 ml of ethylene carbonate (99% pure) and 1.12 ml of 10% (v/v) sulphuric acid (2.0 mmol), a solution of 124.85 g (400 mmol) of isophytol (95% pure) in 400 ml of heptane was added dropwise under an argon atmosphere with stirring at 100°C over a period of 20 minutes. During the addition of isophytol an azeotropic mixture of water/heptane was separated with the help of a water separator. After completion of the addition, the reaction mixture was stirred for another 30 minutes with removal of heptane. The internal temperature rose to about 145°C. After cooling the reaction mixture to about 90°C, 200 ml of heptane were added and the mixture was stirred for about 5 minutes. The upper layer was separated and the lower carbonate layer was extracted with a further 100 ml of heptane. The combined heptane layers were washed with 20 ml of water. After evaporation of the heptane 174.84 g (95.6% yield) of d,l- α -tocopherol were obtained as a brown oil (purity according to GC analysis: 94.2%).

Examples 4-9

[0033] In a flask with reflux condenser, water collector and mechanical stirrer 23.3 g (150 mmol) of 2,3,5-trimethylhydroquinone (98% pure) and the acid catalyst [p-toluenesulphonic acid (p-TsOH) or another sulphur-containing acid] were dissolved in 80 ml of ethylene carbonate. A solution of 36.55 ml (100 mmol) of isophytol (96% pure) in 100 ml of heptane was added within 30 minutes at about 100°C and the reaction mixture was heated for 30 minutes with removal of heptane. The mixture was then heated at 135°C for 30 minutes. The resulting two-phase system was cooled to 80°C, and 100 ml of heptane were added. The two phases were separated and the lower carbonate layer was re-used. The upper heptane layer was concentrated under reduced pressure. The so-obtained and isolated crude d,l- α -tocopherol was analyzed by GC to determine the purity. The results obtained are summarized in the following Table.

Table

Example	Catalyst (weight % based on IP)	Yield (%)	Purity (%)
30	4 p-TsOH (0.13)	92.0	87.0
	5 H ₂ SO ₄ (0.25)	93.3	89.6
	6 C ₂ H ₅ SO ₃ H (0.33)	91.8	88.4
35	7 CH ₃ SO ₃ H (0.35)	95.0	90.8
	8 CF ₃ SO ₃ H (0.37)	95.7	89.7
9	FSO ₃ H (0.12)	92.1	86.4

Example 10

[0034] In a flask with reflux condenser, water collector and mechanical stirrer 23.3 g (150 mmol) of 2,3,5-trimethylhydroquinone (98% pure) and 0.1 g of p-toluenesulphonic acid were dissolved in 80 ml of propylene carbonate. A solution of 36.55 ml (100 mmol) of isophytol (96% pure) in 100 ml of hexane was added within 30 minutes at about 100°C and the reaction mixture was heated for 30 minutes while removing the hexane. The mixture was then heated at 135°C for 30 minutes. The resulting two-phase system was cooled to 80°C and 100 ml of hexane were added. The two phases were separated and the lower carbonate layer was re-used. The upper hexane layer was concentrated under reduced pressure and yielded 39.75 g (92.3 % yield) of crude d,l- α -tocopherol (purity according to GC analysis: 87.0%).

Example 11

[0035] In a flask with reflux condenser, water collector and mechanical stirrer 23.3 g (150 mmol) of 2,3,5-trimethylhydroquinone (98% pure), and 0.1 g of p-toluenesulphonic acid were dissolved in 80 ml of ethylene carbonate. A solution of 36.55 ml (100 mmol) of isophytol (96%) was added within 30 minutes at about 100°C and the reaction mixture was heated for 30 minutes. The reaction solution was then heated at 135°C for 30 minutes and cooled to 80°C. The two phases were separated; the upper layer consisted of 39.23 g (91.1 % yield) of crude d,l- α -tocopherol (purity according to GC analysis: 87.1%).

Claims

1. A process for the manufacture of d,l- α -tocopherol by the acid-catalyzed condensation of trimethylhydroquinone with isophytol in ethylene or propylene carbonate or a mixture of both carbonates or in a mixture of one or both of the carbonates and a non-polar solvent, which process is characterized by carrying out the condensation in the presence of at most 0.4 weight percent based on the weight of isophytol of an acid catalyst selected from sulphuric acid, methanesulphonic acid, ethanesulphonic acid, trifluoromethanesulphonic acid, p-toluenesulphonic acid and fluorosulphonic acid.
10. 2. A process according to claim 1, wherein the catalyst is sulphuric acid or p-toluenesulphonic acid.
3. A process according to claim 1 or 2, wherein the amount of acid catalyst is about 0.1 to 0.4, preferably about 0.1 to 0.2 weight percent, based on the weight of isophytol.
15. 4. A process according to any one of claims 1 to 3, wherein the condensation is carried out in ethylene carbonate or a mixture thereof with a non-polar solvent.
5. A process according to any one of claims 1 to 4, wherein the non-polar solvent is hexane, heptane or petroleum ether, preferably heptane.
20. 6. A process according to any one of claims 1 to 5, wherein the volume ratio of the non-polar solvent to the carbonate in the two-phase solvent system is in the range from 0.3:1 to 5:1.
7. A process according to any one of claims 1 to 6, wherein the condensation is effected at temperatures from about 25. 50°C to about 150°C, preferably from about 80°C to about 120°C, especially at about 100°C.
8. A process according to any one of claims 1 to 7, wherein trimethylhydroquinone is used in a molar excess over isophytol of about 30 to 65%, preferably about 50%.
30. 9. A process according to any one of claims 1 to 8, wherein the condensation is carried out under an inert gas atmosphere, preferably gaseous nitrogen or argon.
10. A process according to any one of claims 1 to 9, wherein about 10 to 100 ml, preferably about 10 to 50 ml, of carbonate solvent (ethylene and/or propylene carbonate) are used per 100 mmol of trimethylhydroquinone and, if a non-polar solvent is additionally used, about 50 to 150 ml, preferably about 70 to 120 ml, of non-polar solvent are used per 100 mmol of isophytol.
35. 11. A process according to any one of claims 1 to 10, wherein isophytol or a solution of isophytol in the employed non-polar solvent is added dropwise to a solution or suspension of trimethylhydroquinone and the acid catalyst in an ethylene or propylene carbonate or a mixture of both carbonates.
40. 12. A process according to any one of claims 1 to 11, wherein the water resulting in the condensation is removed by azeotropic distillation or in the flow of inert gas used.

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EUROPEAN SEARCH REPORT

Application Number
EP 99 10 6507

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim		
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The present search report has been drawn up for all claims				
Place of search	Date of completion of the search	Examiner		
MUNICH	28 July 1999	Hartrampf, G		
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